Litter Decomposition and Nitrogen Mineralization Rates as Affected by Grazing in a Montane Riparian Community

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FINAL REPORT

LITTER DECOMPOSITION AND NITROGEN MINERALIZATION RATES AS AFFECTED BY GRAZING IN A MONTANE RIPARIAN COMMUNITY

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Abstract

Nitrogen budgets in riparian areas have not been well researched. The varying soil conditions found within riparian zones results in complex nutrient cycles. A study was conducted in a montane riparian community in north-central Colorado to assess sources and sinks of carbon (C), nitrogen (N), and phosphorous (P) and decomposition of leaf litter of water sedge (*Carex aquatilis)* and planeleaf willow (*Salix planifolia*). There was a trend for greater litter decomposition during the growing season in grazed as compared to protected areas beneath willow canopies and in the open areas. However, these differences were not significant. Nitrate concentrations were much higher in soils from grazed areas than in excluded areas during most of the growing season. Nitrogen content in forage samples of water sedge from grazed areas was higher than that from exclosures during most of the growing season. Also, dry matter digestibility of water sedge during the latter part of the growing season was greater for previously grazed plants than from those in the exclosures. Phosphorous was only significantly higher in previously grazed forage of water sedge during the July sampling period. Nitrogen and P were greater in plants of planeleaf willow from the short-term grazed paddocks than in willow from the excluded areas. Grazing, therefore, does affect plant and soil levels of N resulting in greater nitrate levels in riparian soils and higher N contents in plants that were previously grazed.

Introduction

Nutrient budgets are not well understood in riparian ecosystems (Green and Kauffman 1989, Groffman et al. 1992, Dahm et al. 1998). These ecosystems are quite complex as they have very high levels of productivity, variable soils as the result of erosion and deposition within small areas, high biodiversity, and provide essential habitat for both terrestrial and aquatic species (Trlica and Leininger 1987, Schulz and Leininger 1991, Clary and Leininger 2000). Riparian soils may be saturated when water overflows stream banks, snow melt occurs, or when water moves laterally from the stream into adjacent banks. However, these same soils may be semiarid during other times of the year when water tables decline, when bank water flows into the stream, and with little precipitation during the summer. Thus, we may have anoxic soil conditions during part of a year and aerated conditions during other times in the year. These varying soil conditions result in complex nutrient cycles where some nutrients may be available for soil microbes and plants during a portion of a growing season and be completely unavailable during other times. In addition, important nutrients such as nitrogen (N) and phosphorus (P) may be lost in runoff in overland flow or as bank discharge to the stream and soil N may be oxidized and lost to the atmosphere as well. If large amounts of these nutrients enter a water body, then eutrophication might occur that can negatively affect aquatic organisms. The riparian zone is, therefore, a dynamic buffer system between uplands and the aquatic environment in filtering nutrients from moving surface and subsurface waters (Dahm et al. 1998). We need to understand these nutrient dynamics much better if we are to make informed decisions on management of soils, vegetation and aquatic resources in these riparian ecosystems.

The purpose of this study was to assess sources and sinks of carbon (C), nitrogen (N), and phosphorus (P) and decomposition of leaf litter in a montane riparian ecosystem. These data

should yield important information on nutrient dynamics of some of the most biologically important nutrients in the ecosystem.

Materials and Methods

This study was conducted from May through September, 1997 in a montane riparian community at the Sheep Creek research area in the Roosevelt National Forest. Sheep Creek is located about 70 km northwest of Fort Collins, Colorado, at an elevation of 2500 m. The soils are a sandy loam to clay loam texture stratified with thin layers of sand or clay of the Fluvaquents series (USDA 1980). In places the water table is less than 30 cm at some time during the spring and summer. Some mottling was evident, indicating recurrent seasonal soil saturation.

Vegetation at the site was dominated by an understory of water sedge (*Carex aquatilis*), tufted hairgrass (*Deschampsia caespitosa*), beaked sedge (*C. rostrata*), and Baltic rush (*Juncus balticus*). The overstory vegetation of the study area was dominated by several willow species. These included planeleaf willow (*Salix planifolia*), Geyer's willow (*S. geyerianna*), yellow willow (*S. lutea*), sandbar willow (*S. exigua*), and peach-leaved willow (*Salix amygdaloides*). This site has grazing exclosures that were established in 1956 in an area where heavy grazing had occurred since the late-1800's (Schulz and Leininger 1990).

Vegetation and soils in these exclosures were sampled during the growing season, as well as in adjacent grazed areas, to determine if previous heavy grazing in the spring significantly affected the concentration of nutrients (C, N, P) in plants and soil during the current year. Data for a dominant shrub, planeleaf willow, and a sedge, water sedge, were collected. In addition, leaf litter for these two species was collected, chemically analyzed, put into nylon mesh decomposition bags, and placed back in the field on the soil surface to determine decomposition rates of litter.

Ion exchange resin bags (Binkley and Matson 1983) were also put in the field at two depths (5 and 25 cm) in the soil to determine N availability for plant and microbial uptake. These data were statistically analyzed and will be discussed in this report.

The grazing treatments were either heavy grazing (approximately 60-70% utilization of current herbaceous vegetation) in late-May or long-term protection from livestock grazing. Each treatment was replicated three times. Three heifers were placed in three paddocks to be grazed within long-term exclosures in the riparian area along Sheep Creek and were allowed to graze for three to four days during May to achieve the heavy utilization desired. Sampling of plants, litter decomposition, and soil nutrient exchange then occurred after plots had been grazed. Forage samples of water sedge and planeleaf willow were collected from individual plants within the grazed or ungrazed plots in June, July, August and September. These samples were analyzed for C and N (LECO CHN-1000), organic matter (OM) and ash (AOAC 1960), and dry matter digestibility (DMD) (USDA 1971) to determine effects of previous grazing on nutrient concentrations in vegetation.

Litter samples of water sedge were collected in open areas, whereas litter samples of planeleaf willow were taken from beneath willow canopies within ungrazed plots. These litter samples were subsampled to determine initial concentrations of C and N. Two gram samples of both species were placed in nylon mesh decomposition bags and placed either in open areas or beneath willow canopies in both grazed and ungrazed plots. These samples were placed on the soil surface in May and collected in September. Samples were returned to the lab at the end of summer where weight change, C, and N were determined on the sample that remained within each bag. Subsamples of both plant forage and litter were ashed to determine OM.

Ion exchange resin (IER) bags were used to estimate soil nitrogen mineralization *in situ* (Binkley and Matson 1983). A mixed-bed (cation + anion) exchange resin was sealed in nylon mesh and buried in the soil profile at 5 and 25 cm depths. Samples were put into both grazed and ungrazed plots in both open areas and under willow canopies at one month intervals from May through September. The bags were collected at one month intervals and new bags were put into the field. Ammonium (NH_4^+) and nitrate (NO_3^-) were extracted from the ion exchange resin with 1 N KCl and the amount of NH_4^+ and NO_3^- was determined (Keeney and Nelson 1982). These repeated incubations of IER bags in the field were used to examine the spatial and temporal patterns of mineral N availability. The major limitation of IER bags is that only relative rates of N mineralization can be determined.

A LECO CHN analyzer was used to determine C and N in both forage and litter samples, while the molybdnate method was used to determine P concentrations. A muffle furnace at 550 C was used to ash samples to determine OM (Nelson and Sommers 1982). Ion exchange resin was used to determine available nitrate and ammonium in the soil.

Data were analyzed using SAS (1996) programs for analysis of variance. The experimental design was a randomized complete block using a 2 x 2 factorial treatment arrangement with repeated measures. Significant differences were accepted at P = 0.05.

Results and Discussion

Litter decomposition during the growing season showed that there were no significant differences in litter decomposition rate between grazed and protected areas and beneath willow canopies and in the open areas in this montane riparian ecosystem. This was true for both the litter of planeleaf willow and that of water sedge. Even though weight loss (i.e. decomposition)

was higher for samples of both species placed in grazed paddocks as compared with those placed in protected areas, the differences were not statistically significant. Litter decomposition in grazed areas might be expected to be greater if grazing stimulated surface microbial activity. High variability in weight loss among samples and the relatively small number of replications (3) probably caused differences in decomposition rate between grazed and protected areas to be non-significant. Arp, et al. (1999) found that decomposition rates of water sedge leaf litter was highly variability among various Rocky Mountain fens.

There was also no significant differences between grazed and protected areas in the amount of C and N that remained in the litter samples after one growing season of decomposition. A low correlation was found between N in initial litter samples and decomposition rate. Aerts and De Caluwe (1997) indicated that high-nutrient *Carex* spp. did not increase nutrient cycling in fens as a result of production of easily decomposable litter. However, Shaw and Harte (2001) found that litter decomposition in mesic sub-alpine meadows in Colorado were highly dependent on temperature and the lignin:N ratio.

Nitrogen was higher in forage samples of water sedge from grazed areas than from exclosures during most of the growing season (Fig. 1). Phosphorus, however, was only significantly higher in previously grazed forage of water sedge during one sampling period (July) in the growing season (Fig. 2). Nitrogen and P were greater in plants of planeleaf willow from the short-term grazed paddocks than in willows from the excluded area (Figs. 3 and 4). In addition, dry matter digestibility of water sedge during the latter part of the growing season was greater for previously grazed plants than similar plants in the exclosures (Fig. 5). These data, therefore, indicate that uptake of N and P by plants in grazed areas may exceed uptake by plants in ungrazed exclosures. Phillips et al. (1999) also had similar findings of greater N and digestibility for

riparian plants that had been grazed the previous growing season. However, it might also be that less forage or browse was produced by these plants under long-term grazing, but the forage produced was higher in nutrients. But, some of our previous work has shown that production of sedges in recently-grazed areas is equal to or greater than that of production in exclosures (Wheeler et al. 2002). These results, therefore, may indicate stimulation of nutrient uptake and growth by riparian plants that have been grazed. Modification of the surface soil by grazing and trampling might cause an increase in mineralization of nutrients and greater nutrient availability for plant uptake. This important interaction should be investigated in greater detail.

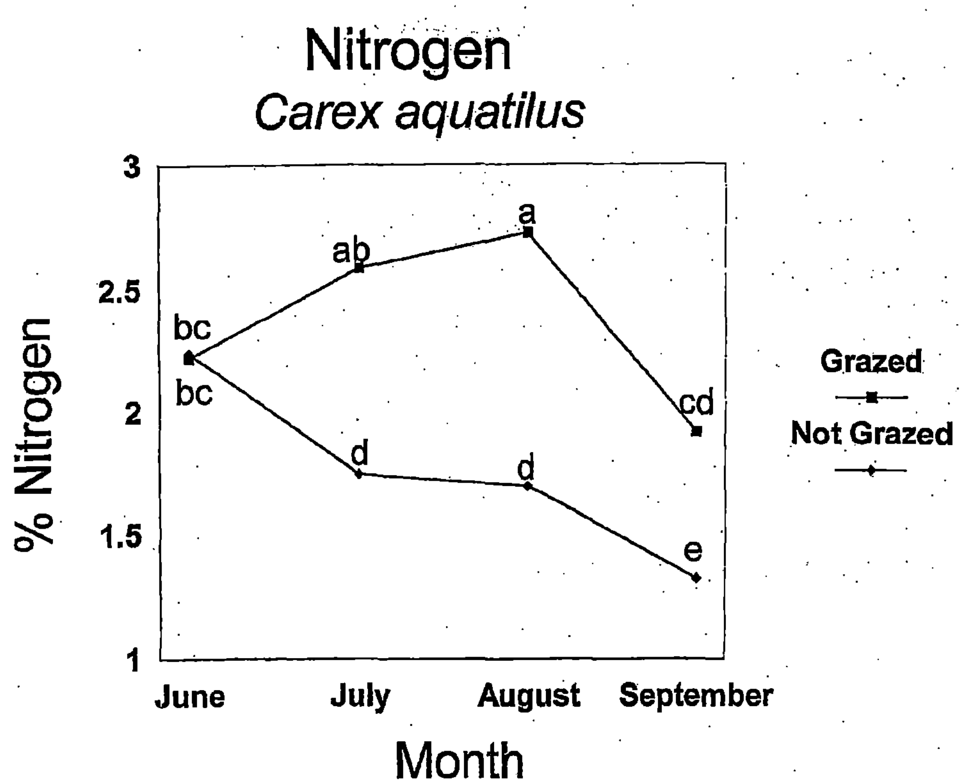

Figure 1. Nitrogen concentration in forage samples of *Carex aquatilis* throughout the growing season in grazed and ungrazed plots.

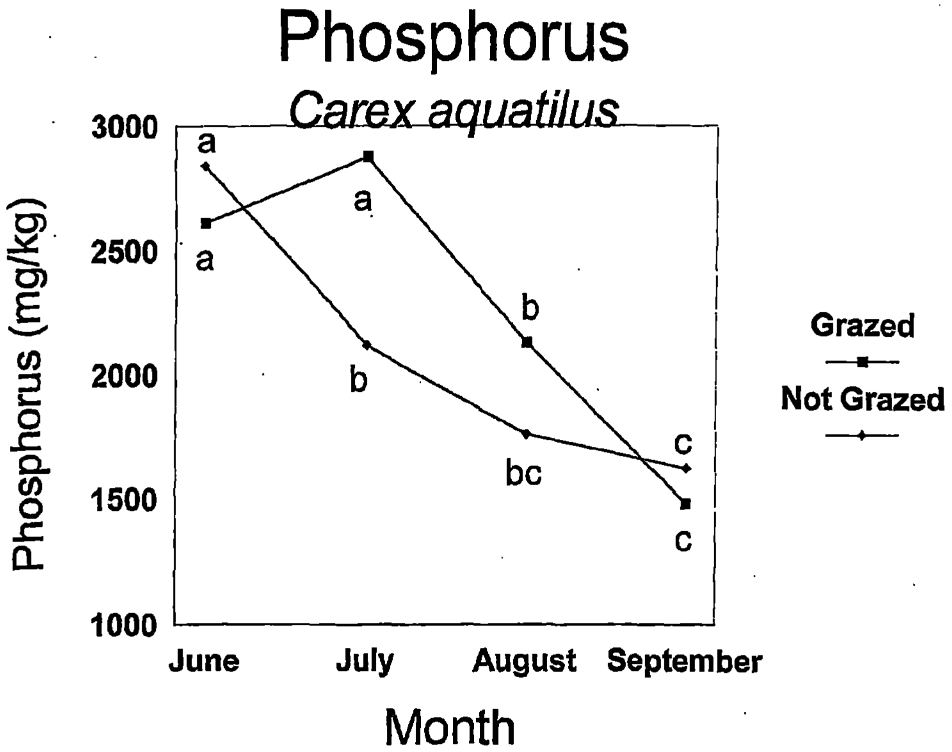

Figure 2. Phosphorous concentration in forage samples of *Carex aquatilis* throughout the growing season in grazed and ungrazed plots.

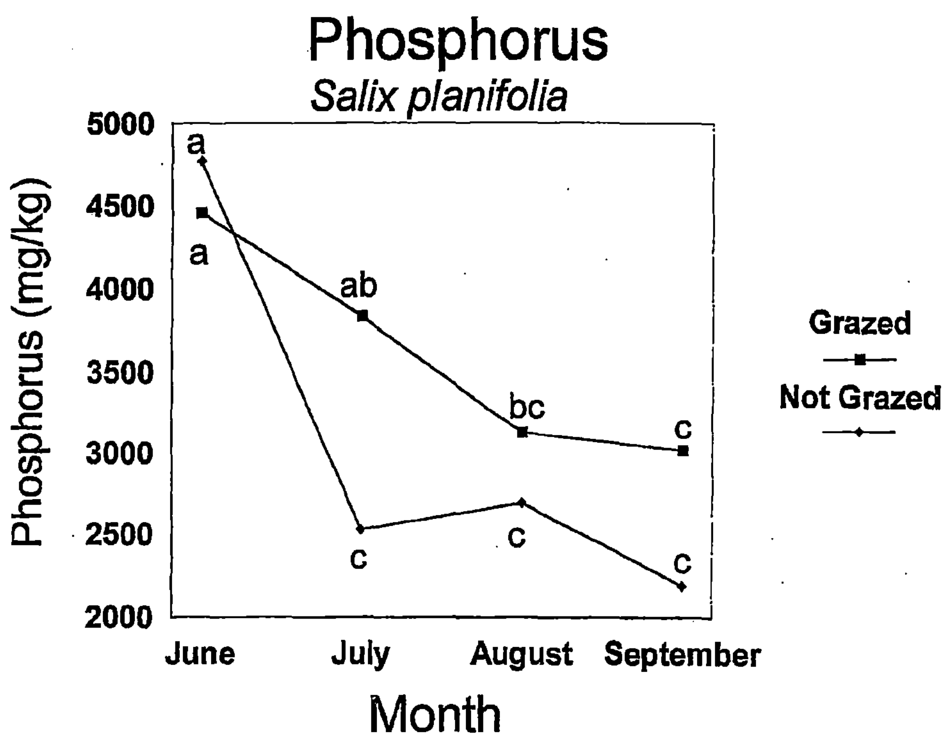

Figure 3. Phosphorous concentration in forage samples of *Salix planifolia* throughout the growing season in grazed and ungrazed plots.

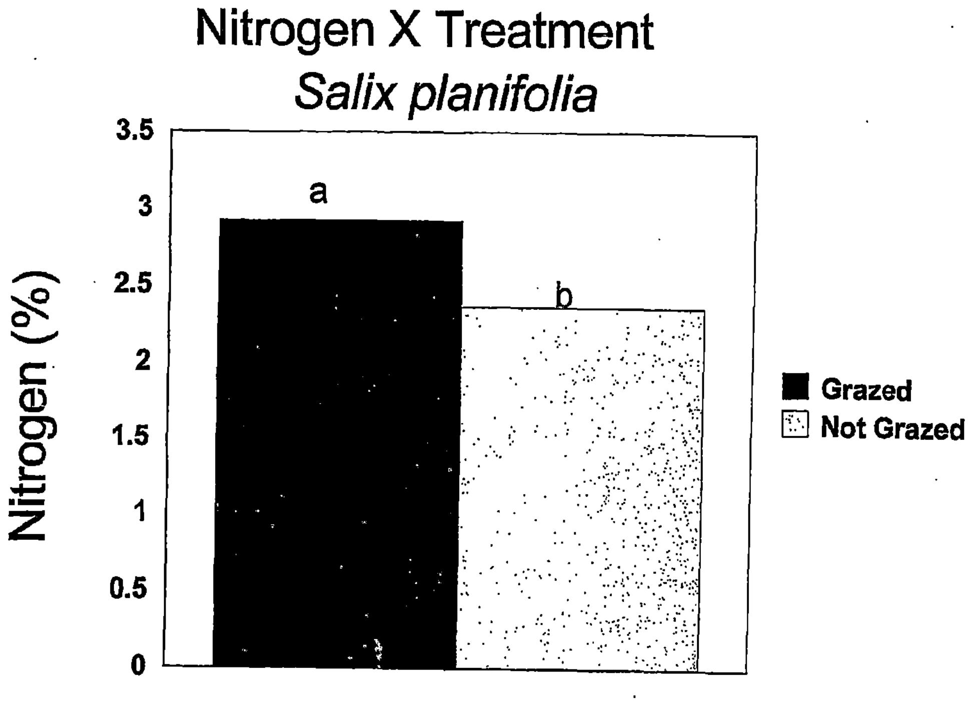

Figure 4. Nitrogen concentrations in *Salix planifolia* leaves averaged across 4 sampling periods as affected by livestock grazing.

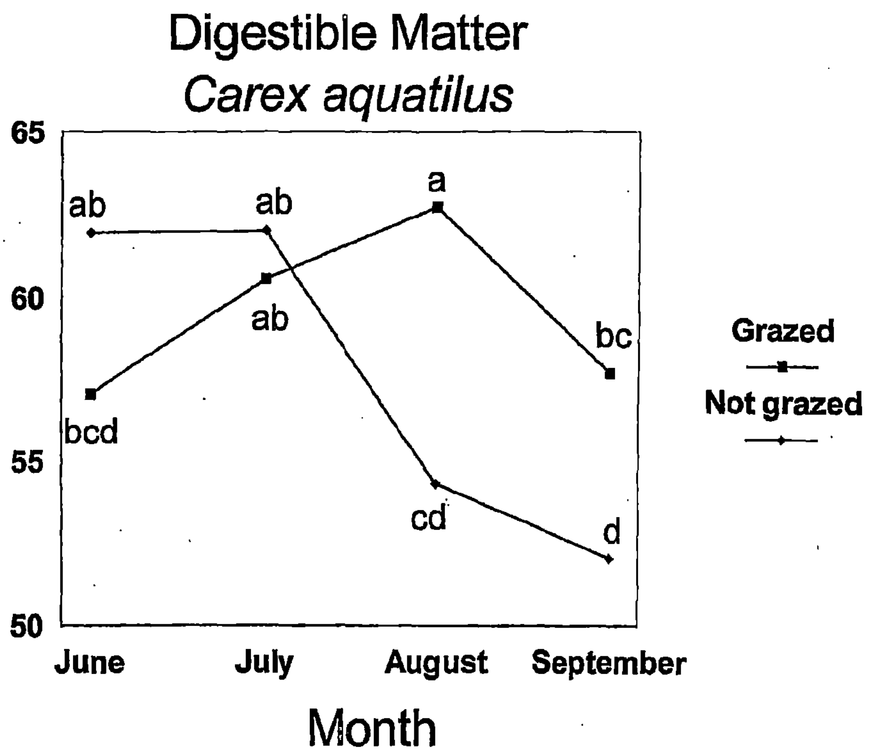

Figure 5. Dry matter digestibility in forage samples of *Carex aquatilis* taken throughout the growing season in grazed and ungrazed plots.

Ammonium (NH_4) and nitrate (NO_3) levels were determined at monthly intervals throughout the growing season using ion exchange resin put into nylon bags and buried at 5 and 25 cm depths in either open areas or beneath willow canopies in both grazed and excluded riparian areas. Results indicated high availability of ammonium at the beginning of the growing season at the shallow depth, but with rapid plant growth this ammonium was taken up and immobilized quickly (Fig. 6). Little change in available ammonium was noted at the 25 cm soil depth. Ammonium concentrations also declined to a lower level during the rapid growth period in soils beneath the willow canopy than in the open (Fig. 7).

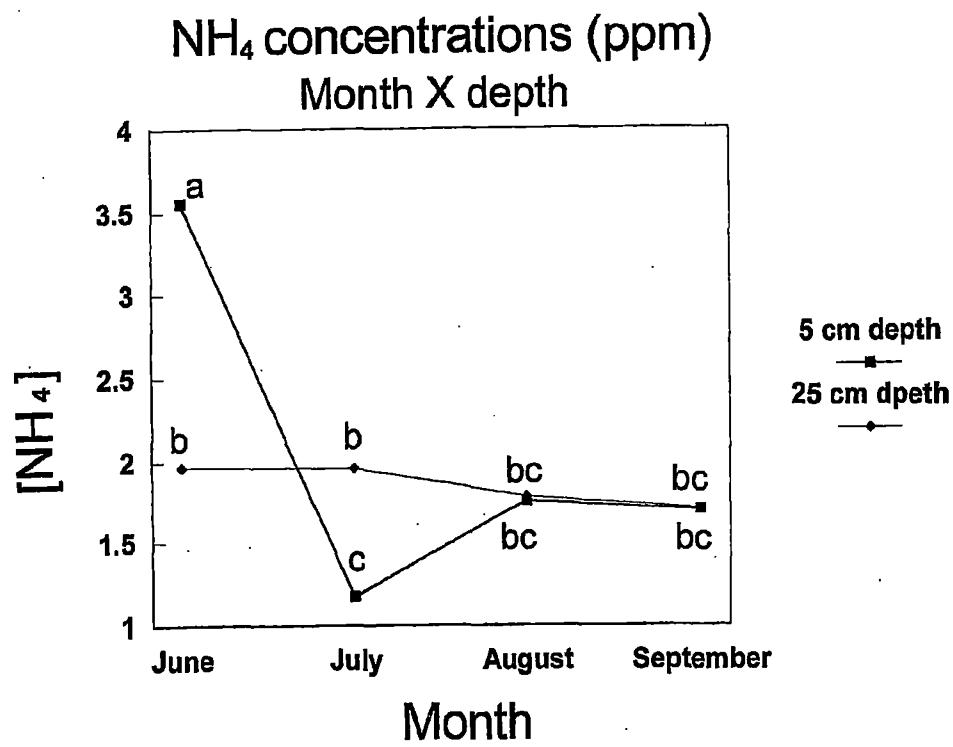

Figure 6. Ammonium concentrations in soils at 2 depths throughout the growing season averaged across 2 locations.

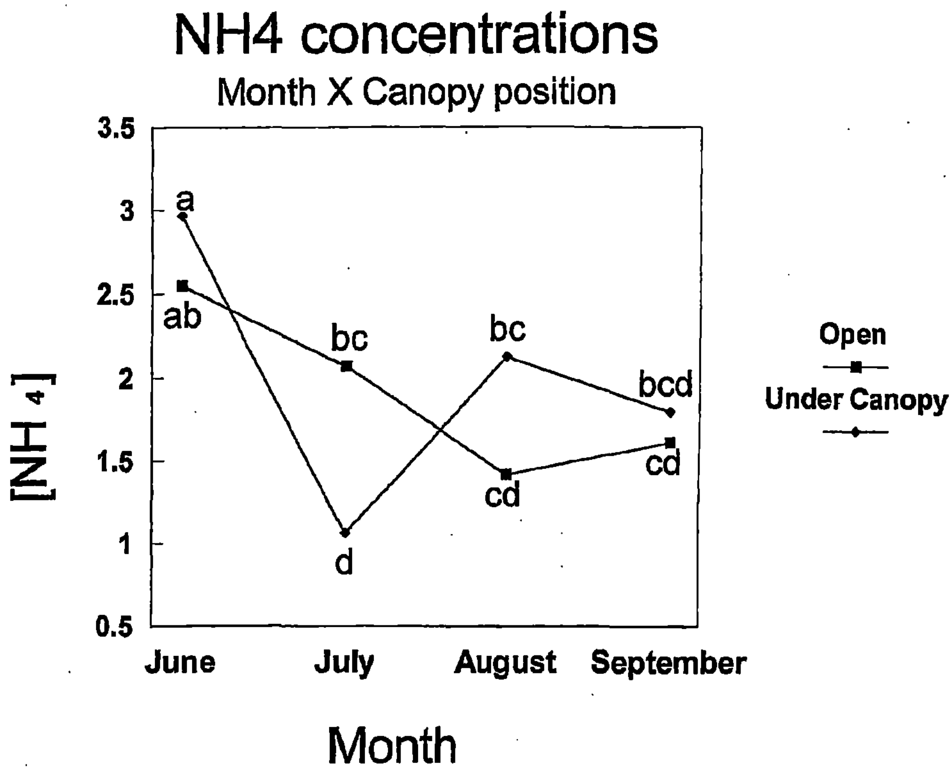

Figure 7. Ammonium concentrations in soils in the open and under willow canopy averaged across 2 soil depths.

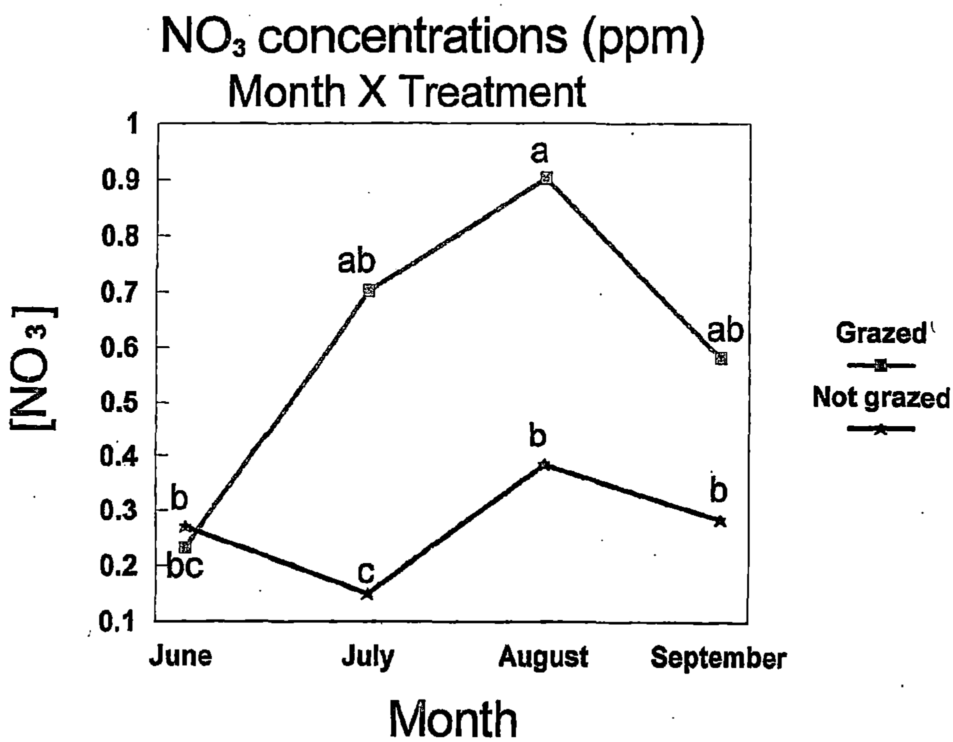

Figure 8. Nitrate concentrations in soils averaged across 2 locations as affected by livestock grazing.

Nitrate concentrations were much higher in soils from grazed areas than in excluded areas during most of the growing season (Fig. 8). Since nitrate is quite soluble, it may move easily with subsurface water flow and enter the stream if it is not taken up by plants and microbes in the system. Hence it represents a greater potential pollutant threat than does ammonium that is often absorbed to soil colloids. Nitrates in soils beneath the canopies of willow were usually less than that in soils from open areas (Fig. 9). The combined uptake of nitrates by both willows and herbaceous species beneath the canopies may explain the lower level of nitrates observed beneath shrub canopies. Also denitrification rates in the two micro sites may have varied. Seitzinger (1994) found that denitrification rates in wetlands was related with organic matter mineralization.

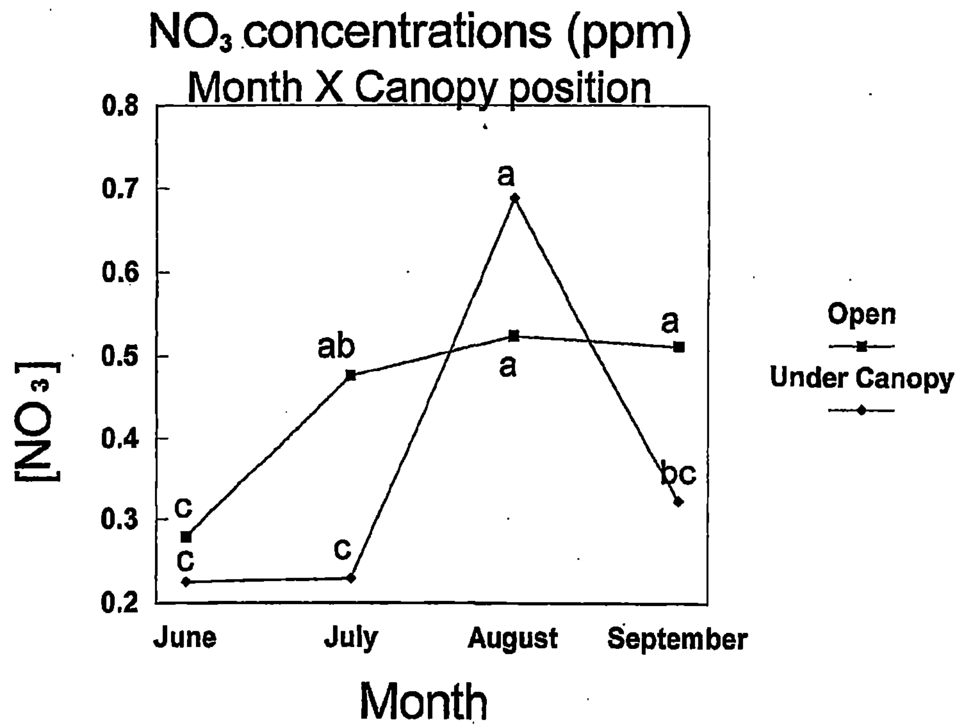

Figure 9. Nitrate concentrations in soils averaged across grazing treatments in open and under willow canopy.

Summary and Conclusions

This study has yielding valuable information on nutrient levels in vegetation and in soils of a montane riparian ecosystem and how these levels fluctuate with time, soil depth, and grazing interactions. Data on litter decomposition rates, however, did not indicate significant differences in decomposition rates in the open or under willow canopies in either grazed or protected conditions, even though there was some indication that decomposition rates might be greater for litter in grazed paddocks than in protected areas. Higher nitrate availability and plant uptake in grazed paddocks may indicate more rapid mineralization with disturbance. There is also the possibility for more nitrate to enter the stream through surface or subsurface flow if vegetation and microbes in grazed areas do not take up this additional N (Trlica et al. 2000). Through a better understanding of the soil-microbe-plant interactions in nutrient uptake, utilization and distribution, we should be able to do a better job of managing these ecosystems to allow the riparian buffer zone to be an efficient sink of nutrients for plant uses and maintain stream water quality for desirable aquatic habitat and downstream users of this water.

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